

black streaks; palpi white towards base; pectus, legs, and ventral surface of abdomen white, the femora and tibiæ tinged with brown, the fore tibiæ with blackish band at extremity. Fore wing grey tinged with brown; a slightly curved blackish antemedial line; a narrow black discoidal lunule; postmedial line blackish, slightly bent outwards and waved from vein 5 from above 2, then retracted to below angle of cell and slightly sinuous to inner margin; cilia whitish tinged with brown and with a blackish line at base. Hind wing grey tinged with brown; an oblique black discoidal bar; postmedial line blackish, bent inwards and almost obsolete on vein 2, then oblique to tornus; cilia whitish tinged with brown and with a blackish line at base. Underside white, the fore wing tinged with brown except on inner area.

Hab. PERU, La Mercede, Chanchamayo (*Watkins*), 1 ♂ type.
Exp. 32 mm.

[To be continued.]

PROCEEDINGS OF LEARNED SOCIETIES.

GEOLOGICAL SOCIETY.

December 5th, 1917.—Dr. Alfred Harker, F.R.S., President,
in the Chair.

A Demonstration on the Application of X-Rays to the Determination of the Interior Structure of Microscopic Fossils, particularly with reference to the Dimorphism of the Nummulites, was given by E. Heron-Allen, F.L.S., F.G.S., Pres.R.M.S., and J. E. Barnard, F.R.M.S.

Mr. HERON-ALLEN said that in the year 1826 Alcide d'Orbigny published among the innumerable, and for many years unidentified, *nomina nuda* that compose his 'Tableau Méthodique de la Classe Céphalopodes' the name *Rotalia dubia*. This species was left untouched by Parker & Jones in their remarkable series of articles 'On the Nomenclature of the Foraminifera.' The French naturalist G. Berthelin was the first investigator to unearth and make use of the 'Planches inédites' which had been partly completed by d'Orbigny for the illustration of his great work upon the Foraminifera, a work that was never published. Working with Parker & Jones's paper, Berthelin made for his own use careful tracings of 246 of A. d'Orbigny's unfinished outline-sketches. These sketches were never elaborated by d'Orbigny upon the 'Planches,' which are still preserved in the Laboratoire de Paléontologie under the care of Prof. Marcellin Boule; among them was found the sketch of *Rotalia dubia*. On the death of Berthelin the tracings passed into the possession of Prof. Carlo Fornasini of Bologna, who reproduced them all in a valuable series of papers published between the years 1898 and 1908. Fornasini's opinion

was that the organism depicted by d'Orbigny was doubtfully of Rhizopodal nature, and that it was probably referable to the Ostracoda. The speaker said that he had examined the d'Orbigny type-specimens in Paris in 1914, and had noted that *Rotalia dubia* was a worn and unidentified organism, resembling an Ostracod.

There the matter rested until Mr. Arthur Earland and the speaker, while examining the material brought by Dr. J. J. Simpson from the Kerimba Archipelago (Portuguese East Africa) in 1915, discovered one or two undoubted Foraminifera of an unknown type, which resembled Berthelin's tracing. Prof. Boule kindly sent the d'Orbigny type-specimen to London, and the Rhizopodal nature of *Rotalia dubia* was established. It is not a *Rotalia*, and it must await determination until more specimens are obtained. It has been named provisionally *Pegidia papillata*. There were two or three forms of the organism, but only one perfect specimen of the d'Orbigny type; and it was undesirable to risk destruction by cutting a section of it. In these circumstances Mr. Barnard was approached, and he experimented with the object of ascertaining the interior structure of the shell by means of the X-rays. His results were extraordinarily promising, and led to further experiments.

The speaker showed on the screen photographs of the common and dense Foraminifer *Massilina secans* (d'Orb.), followed by a skiagraph of the same. A skiagraph of the still denser test of *Biloculina bulloides* d'Orb. shows the arrangement of the earlier chambers as clearly as it is indicated in Schlumberger's beautiful sections. The application of X-rays to the dense imperforate shells *Cornuspira foliacea* (Philippi) produced skiagraphs showing the dimorphism of the shells, both megalo- and microspheric primordial chambers being clearly distinguishable. Such results led to the extension of the experiments to the agglutinated arenaceous forms, of which sections are made with extreme difficulty. The skiagraph of *Astrorhiza arenaria* Norman shows the internal cavities that contained the protoplasmic body. Two arenaceous forms, *Botellina labyrinthica* Brady and *Jaculella obtusa* Brady, that are almost identical in external appearance, are distinguished at once by their respective skiagraphs, the one exhibiting a simple tubular cavity, the other appearing labyrinthic.

Mr. Barnard subsequently experimented on still more difficult material. The massive *Operculina complanata* DeFrance, the umbilical portion of which is obscured by a mass of secondary shell-substance, furnished a clear skiagraph that showed some curious distortions of the internal septa. Similar results were obtained in the case of *Orbiculina adunca* (Fichtel & Moll), another species overlaid with shell-matter. *Cyclamina cancellata* Brady is an arenaceous form, composed of softer mud and sand, studded with coarse sand-grains which make section-cutting almost an impossibility. The skiagraphs, however, reveal the primordial chamber, and establish the character of this form.

The determination of the Nummulites, depending as it does on a knowledge of the internal structure of the test, is greatly

facilitated by the application of X-rays, which removes the necessity of splitting it or cutting sections through it.

The speaker showed ordinary photographs and skiagraphs, made at slightly varying azimuths, of *Nummulites laevigata* and *N. variolaria*, forms that strew the shores of Selsey Bill. A particularly notable result was obtained in the case of *N. gizehensis*, an organism that forms the dense masses of Nummulitic Limestone of which the Pyramids of Egypt and the Citadel at Cairo are built.

Mr. BARNARD said that, although the utilization of X-rays to determine the internal structure of various bodies was well known, he was not aware that the method had been successfully applied to small objects, such as Foraminifera. After he had begun his experiments he found that M. Pierre Goby had done some work in this direction in France, but the method as he described it is surrounded with considerable mystery and elaboration of apparatus, which appear quite unnecessary. The speaker's results were arrived at independently; in fact, they are really a side issue.

His original experiments were directed rather towards the use of X-rays in obtaining magnified images, altogether apart from the usual skiagraphic methods in which a shadowgraph is, in fact, all that can be produced. The primary object has not yet been achieved, although there is some reason to hope that it may ultimately come to pass. The results shown by Mr. Heron-Allen are obtained by quite simple means. A very narrow beam of X-rays, such as would be termed 'a parallel beam' when speaking in terms of ordinary light, is allowed to impinge on the object, the latter being in contact with the photographic plate. The negative produced is, therefore, of the same size as the object. Photographic enlargement is then resorted to, and the result had been shown on the screen. There are two points that require careful attention to if success is to be achieved.

The quality of the X-rays must be suited to the object. In nearly all cases of small objects, what are known as 'soft' X-rays must be used, and the degree of softness is the *crux* of the whole matter. The photographic plate must be of exceedingly fine grain, otherwise the amount of enlargement that can be obtained is very limited. Difficulties in this direction have been overcome, and Mr. Heron-Allen has stated that the results are of considerable biological value.

Dr. A. SMITH WOODWARD, F.R.S., V.P.G.S., exhibited a radiogram of the original slab of lithographic stone containing the skeleton of *Archæopteryx*, made for the British Museum by Dr. Robert Knox in 1916. It was evident that the penetrability of the fossil bones to the X-rays was the same as that of the surrounding matrix. The only portions of the skeleton visible in the radiogram were those more or less raised above the general surface of the slab. This result accorded with that obtained by Prof. W. Branca when he similarly experimented with the Berlin specimen of *Archæopteryx*.